

System design for turbidity control in aquaponic ponds

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ABSTRACT

Aquaculture is fish farming, and hydroponics is the cultivation of plants/vegetables without soil, which means utilizing water and growing media. Aquaponic systems are a combination of fish farming (aquaculture) and soil-less plant/vegetable farming (hydroponics), creating a mutually beneficial relationship. This research aims to design and implement an automated system capable of monitoring and controlling the water turbidity level in aquaponic ponds using the SEN0189 sensor integrated with the Internet of Things (IoT) platform. The developed system utilizes a turbidity sensor, float switch, NodeMCU ESP8266 microcontroller, and connection to the Firebase cloud to enable real-time remote monitoring. The control logic in the system is designed to be able to take automatic water draining and filling actions based on the detected turbidity level parameters. Tests were conducted 98 times, showing a sensor success rate of 92% with 8% non-conforming readings due to program logic mismatches. The tests also revealed the significant influence of environmental lighting, where sensor results at night showed higher values despite clear water conditions. In addition, the system successfully avoided overlapping processes between draining and filling, with an operational success rate of 100% in the overall device test. The results show that the system is effective and reliable for maintaining water quality in aquaponic systems, as well as providing users with the convenience of remotely monitoring and managing water conditions through an IoT connection. This system can be an efficient alternative solution to support the success of fish and plant farming in household and commercial scale aquaponics.

Keywords: Aquaponics; ESP8266; Float Switch; SEN0189 Sensor; Water Turbidity.

1. INTRODUCTION

Hydroponics is an agricultural technique that uses water and does not use soil as a growing medium. Hydroponic farming system is one of the alternatives that can be used to increase agricultural productivity, especially on limited land [1]. Various cultivation methods are being developed, including the aquaponic system. The aquaponic system can be maximally utilized on a small area of land and can be used in home gardens. This system is a combination of aquaculture and hydroponics so as to create a symbiotic mutualism or called mutual benefit. Aquaponics is a combination of aquaculture and hydroponic systems that can be a solution to overcome limited land and water resources and improve food security. In aquaponic systems, water quality in fish farming is one of the main requirements for the success of the cultivation process [2]. Water from the fish pond cannot be flowed directly to the plants but must go through a filter system and a nitrification system. The aim is to precipitate fish waste and convert nitrogen-containing elements such as urea and ammonia that are abundant in fish ponds. This is because plants only absorb nitrogen elements in the form of ions. In addition, nitrification prevents plants from being poisoned due to the dominance of nitrogen-containing elements [3].

This research makes a system design for turbidity control in aquaponic ponds using turbidity sensors and float switches for draining and filling the pond. In addition, this system is designed to



automatically monitor and control the level of water turbidity in real-time in aquaponic ponds, and can be integrated with IoT technology to be efficient and easy to monitor remotely.

The level of water quality is one of the parameters [4]. In designing an aquaponic system, it is necessary to pay attention to various aquarium water quality factors that affect the circulation of the system [5]. Water is an important medium in aquaponic systems because it is a place for fish to grow and a source of food for plants. Water is very easily polluted and contaminated with harmful substances during the maintenance process. Therefore, it is necessary to maintain the quality of aquaponic water during the cultivation process [6].

Turbidity is an optical phenomenon in solution that is measured based on how much light is taken up and emitted by the matter in the water [7]. Turbid water can be caused by various factors, including dissolved solids that are inorganic and organic. Turbidity sensor is an instrument used as a standard testing tool to determine the degree of turbidity of a water. If dirty water is not treated, it can inhibit fish growth [8]. This sensor is able to detect changes in light intensity caused by the presence of particles in water. The degree of water clarity is one of the parameters to determine the condition of water so that it can be utilized by living things. There are also other parameters that can be used as a reference, such as: pH value [9], Conductivity, Temperature, Total Dissolved Solid (TDS) [10].

The contribution that can be made to this research is to use one sensor and two actions, namely the turbidity sensor (Turbidity sensor) to detect the degree of water turbidity and the action is to drain and fill the pond using the float switch as the switch. During draining, no other actions are performed simultaneously. If the pool shows very clear water, then there is no action, but if the Turbidity value is greater than 129, then there is an action to drain the pool until there are 26 liters of pool left or 20%.

2. METHOD

Figure 1 shows the prototype design with TDS sensor input that detects plant ppm and pH sensor that detects the pH of the water supplied to the plants. Turbidity sensor detects the level of turbidity in the aquaponic pond. The inputs are processed by the Node MCU microcontroller. This signal is processed by a relay and opens a solenoid valve to reduce and maintain the amount of water until the float switch sensor turns off. The diagram depicts an Internet of Things (IoT) based automatic monitoring and control system consisting of: physical sensors (pH, TDS), pump automatic control, local processing (Arduino), cloud connection (ESP32 and Firebase), and user interface (IoT Dashboard).

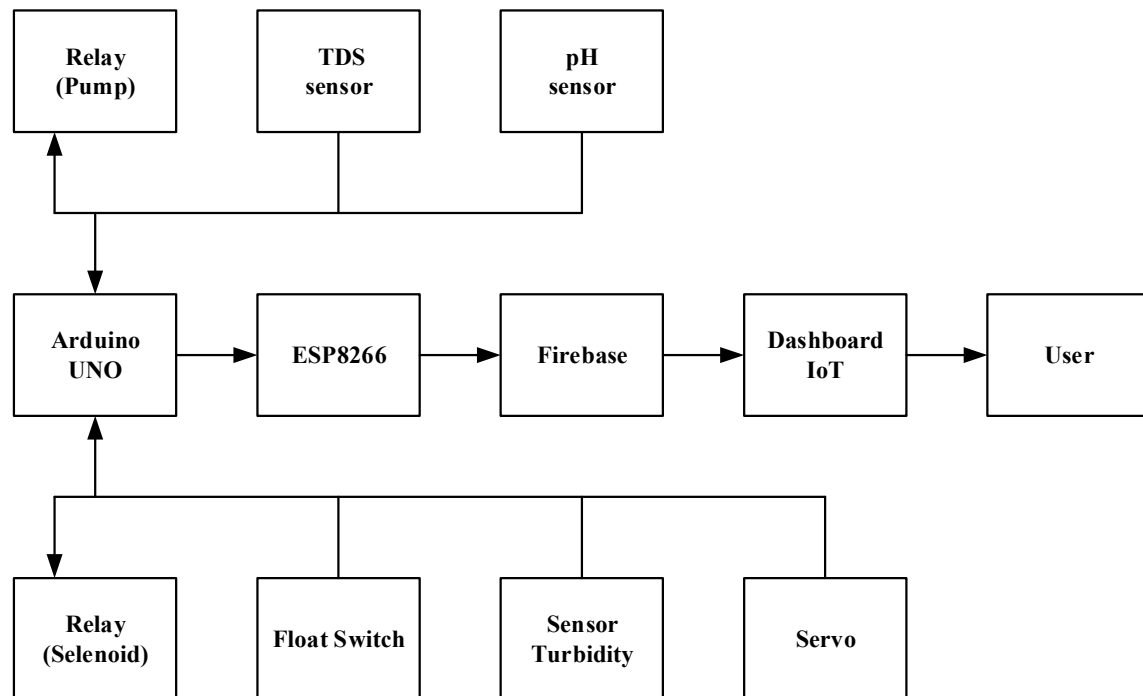


Figure 1. Block diagram of the system

ESP8266

The NodeMCU ESP8266 is a module from the ESP8266 family of IoT (Internet of Things) platform modules of the ESP-12 type. The ESP32 is a microcontroller created by Espressif Systems and is an advancement from its earlier version, the ESP8266 [11]. The ESP8266 module is an inexpensive yet very powerful platform for online communication or control. Both stand alone and using an additional microcontroller in this case Arduino as the controller. In terms of function, this module is almost the same as the Arduino module platform, but the difference is that it is specifically designed to connect to the Internet [12]. ESP8266 is a Wi-Fi module [13], that functions as an addition to microcontrollers such as Arduino to connect directly to Wi-Fi networks and establish TCP/IP connections [14]. Based on Figure 1, the ESP8266 functions as a Wi-Fi module, receiving data from the Arduino and sending it to the cloud (Firebase).

SEN0189 Sensor

The SEN0189 sensor measures or detects the level of water turbidity [15]. The DFRobot SEN0189 sensor works according to changes in light intensity. This is because the particles are mixed with water. The change in light intensity emitted will vary with the change in turbidity of the measured water. This is then converted into electrical parameters so that it can be expressed as a water turbidity value in NTU units. The data from this sensor is processed by the NodeMCU ESP8266 microcontroller. From the system block diagram, the SEN0189 sensor is used to read the turbidity of the water, because basically the turbidity particles cannot be seen by the direct eye.

Servo MG996R

A servo motor is a device that acts as a rotating motor with a closed-loop feedback control system (servo) designed to control and ensure the angular position of the output shaft [16]. The servo motor consists of several components. Consists of a DC motor, gear circuit, control circuit and potentiometer. Gears placed on the DC motor shaft are used to slow down shaft rotation and increase servo motor torque. While the potentiometer changes the resistance as the motor rotates to set the shaft angle position limit [17].

Arduino Uno

Arduino UNO is a microcontroller board based on ATmega328P [18]. The Arduino Uno has 14 digital I/O pins (6 of which can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connector, a power jack, an ICSP header, and a reset button. The Arduino UNO has everything needed to support any microcontroller. Simply connect to a computer with a USB cable, or power it up with an AC-DC adapter, or battery to start the process [19]. Based on Figure 1, Arduino UNO is tasked with reading data from TDS and pH sensors. Arduino UNO also controls relays (pumps) based on certain logic, then sends data to ESP32.

Float Switch

A Float Level Switch is a type of liquid level sensor that uses a float to operate the switch. Floats are often used to control other devices such as alarms and pumps when the water level rises or falls to a certain point. A Float Level Switch is a continuous level sensor with a magnetic float that moves up and down as the water level changes. The movement of the float creates a magnetic field that moves a closed reed switch on the stem of the level sensor, opening or closing the switch. So, a Float Level Switch detects the level of liquid in a tank or container. It floats above the liquid surface and acts as a mechanical switch when the liquid level rises or falls.

Flowchart System

Based on Figure 2, the microcontroller will try to connect to the internet via Firebase when the turbidity sensor detects water exceeding 220. If the connection is successful, a notification will be sent. If the connection fails, the pool servo only releases 20% of the water, the bottom float switch becomes active. If the faucet solenoid valve is working properly, the pool will be filled until it reaches 100% capacity. Then, if successful, the solenoid valve will stop and the system will be completed.

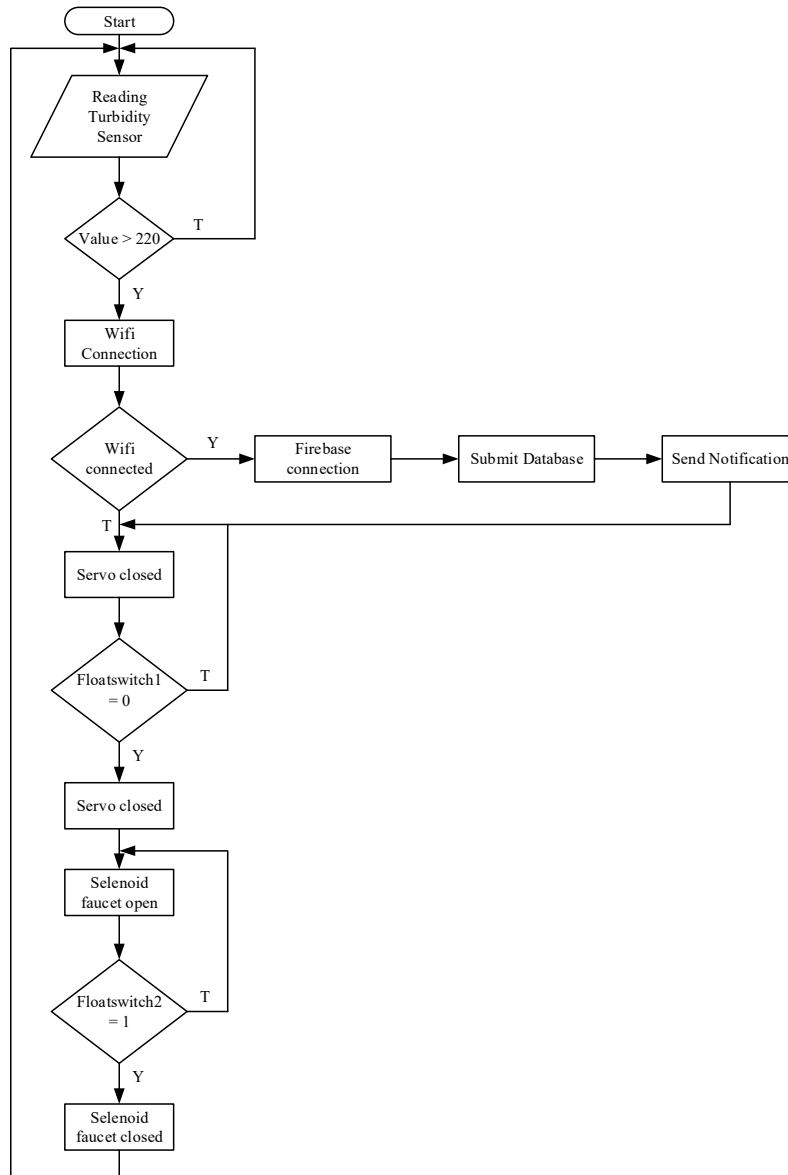


Figure 2. System flowchart

Tool Design

Figure 3 shows the design of the aquaponic apparatus, with pipes for aquaponic plants at the top and a pond for fish farming at the bottom.

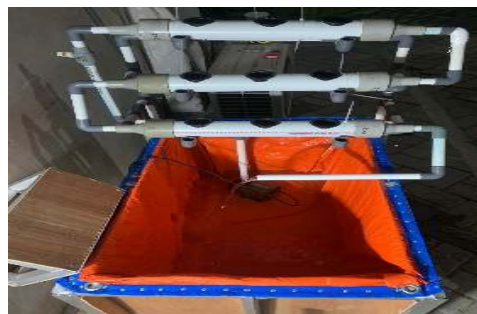


Figure 3. Tool design

The sensor for measuring turbidity is placed at the very top of the aquaponic pond. Meanwhile, there are two different locations for the float switch in the pool. At the first location, the float switch detects when the water has reached its maximum volume, while at the second location, the float switch functions when the remaining water volume is approximately 20% of the total pool capacity. A turbidity sensor placed at the top of the pool can monitor water quality precisely, while float switches installed at two points provide important data about water levels. This information can assist in regulating water flow and maintaining the best conditions for aquatic organisms in the system.

Sensor Priority

This research uses 2 sensors and 4 actions, namely the PH sensor to determine the acidity of the water, while to stabilize the acidity of the water the action is to add pH up and pH down, and the TDS sensor to determine the PPM (Parts Per Million) of water, while the action is to add AB Mix and drain the fish pond. The four activities above do not take place simultaneously and must be carried out sequentially. Therefore, this is where the PH sensor detection first begins. If the pH sensor detects the acidity of the fish pond water is less than 6, the action taken is to add pH up to increase the pH of the pond water, and if the detected pH of the pond is greater than 7, the action taken is to add pH down, a liquid to lower the pH level of the fish pond water. If the pH sensor detects the pH of the water between 6 to 7, the action is taken based on the TDS sensor. If the TDS sensor detects a water ppm value smaller than 560, the action is to add AB Mix to increase the water ppm value. If the TDS sensor detects a water ppm value greater than 840, a fish pond draining action is triggered.

So here the most important sensor is the pH sensor because the acidity of the water is very important for aquaponic plants and fish. Only one action is executed at a time until the specified time is completed. When the waiting period is over, the next sensor is re-selected, which is required to take action.

3. RESULTS AND DISCUSSION

SEN0189 Sensor testing

The SEN0189 Turbidity Sensor test was conducted by connecting the MCU node to Firebase to obtain the turbidity value. The test was conducted using a large amount of food that settles in the pond, causing the pond water to become cloudy. In Table 1, the test was performed 98 times by measuring 1 liter of water, to which 5 grams of fish food was slowly added for 5 seconds each. The results are shown in Table 1.

Table 1. SEN0189 Sensor test results

No	Water type	Value range	Sensor value	No	Water type	Value range	Sensor value
1	1	0 - 88	38.76	46	2	89 - 220	219.82
2	1	0 - 88	38.76	47	2	89 - 220	217.35
3	1	0 - 88	38.76	48	2	89 - 220	219.81
4	1	0 - 88	38.76	49	2	89 - 220	219.81
5	1	0 - 88	38.76	50	2	89 - 220	219.81
6	1	0 - 88	38.76	51	2	89 - 220	219.81
7	1	0 - 88	38.76	52	2	89 - 220	219.81
8	1	0 - 88	60.3	53	2	89 - 220	219.81
9	1	0 - 88	60.8	54	2	89 - 220	219.81
10	1	0 - 88	60.8	55	2	89 - 220	219.81
11	1	0 - 88	60.8	56	2	89 - 220	219.81
12	1	0 - 88	71.4	57	2	89 - 220	219.81
13	1	0 - 88	71.4	58	2	89 - 220	219.81
14	1	0 - 88	70.9	59	2	89 - 220	219.81

No	Water type	Value range	Sensor value	No	Water type	Value range	Sensor value
15	1	0 - 88	60.8	60	2	89 - 220	219.81
16	1	0 - 88	60.8	61	3	greater than 220	221.2
17	1	0 - 88	60.8	62	3	greater than 220	221.2
18	1	0 - 88	60.8	63	3	greater than 220	221.2
19	1	0 - 88	85.4	64	3	greater than 220	221.2
20	1	0 - 88	85.4	65	3	greater than 220	221.2
21	1	0 - 88	85.4	66	3	greater than 220	221.2
22	1	0 - 88	87.6	67	3	greater than 220	197.2
23	1	0 - 88	87.6	68	3	greater than 220	197.2
24	1	0 - 88	87.6	69	3	greater than 220	197.2
25	1	0 - 88	87.6	70	3	greater than 220	197.2
26	1	0 - 88	87.6	71	3	greater than 220	301
27	1	0 - 88	87.6	72	3	greater than 220	301
28	1	0 - 88	87.6	73	3	greater than 220	201.94
29	1	0 - 88	87.6	74	3	greater than 220	201.94
30	1	0 - 88	87.6	75	3	greater than 220	201.94
31	2	89 - 220	128.85	76	3	greater than 220	201.94
32	2	89 - 220	128.85	77	3	greater than 220	301
33	2	89 - 220	190.8	78	3	greater than 220	301
34	2	89 - 220	190.8	79	3	greater than 220	301
35	2	89 - 220	190.8	80	3	greater than 220	301
36	2	89 - 220	190.8	89	3	greater than 220	301
37	2	89 - 220	200.35	90	3	greater than 220	301
38	2	89 - 220	217.35	91	3	greater than 220	301
39	2	89 - 220	217.35	92	3	greater than 220	301
40	2	89 - 220	217.35	93	3	greater than 220	301
41	2	89 - 220	217.35	94	3	greater than 220	301
42	2	89 - 220	217.35	95	3	greater than 220	301
43	2	89 - 220	217.35	96	3	greater than 220	301
44	2	89 - 220	217.35	97	3	greater than 220	301
45	2	89 - 220	219.81	98	3	greater than 220	301

In this study using number one for very clear water, number two for clear water, and number three for cloudy water. Table 1, it can be seen that the sensor value is in accordance with the predetermined value limit, except for the 67th trial to the 70th trial, which is 197.2. The sensor value does not match the limit which must be greater than 220. Likewise, the 73rd trial to the 76th trial which is 201.94, does not match the specified limit which is greater than 220.

It can be said that the sample gets a value of 38.76 when not given food. Then slowly added 5 grams of food and obtained a maximum value of 87.6. Next, 5 grams of food was given again and the maximum value was 219.81. In this study there were 8 errors out of 98 tests, and 8% of these errors were caused by not meeting the program requirements.

Discussion: The SEN0189 sensor showed a fairly sensitive and accurate response to increasing turbidity levels. The sensor value increases as the amount of suspended particles from fish feed decomposes in the water. This confirms that the sensor is able to effectively differentiate between clear, medium and turbid water conditions. Data from tests 1-7 showed a fixed value of 38.76, which could indicate the stability of the sensor in clear water conditions. The sharp spike in value after continuous addition of feed indicates the sensor works in real-time and is consistent with changing water conditions.

Testing turbidity sensor action on an aquaponic pond

This test is carried out to determine the level of turbidity of the pool. This test is carried out when the pool is filled with new water, the aim is to obtain the value of the SEN0189 sensor.

Table 2. Analysis of sensor data in aquaponic ponds during the day and night

No	Water type	Sensor value during the day	No	Water type	Sensor value at night
1	2	120.24	1	2	217.14
2	2	120.24	2	2	217.33
3	2	120.24	3	2	217.33
4	2	120.24	4	2	217.33
5	2	120.24	5	2	216.14
6	2	120.24	6	2	216.14
7	2	120.24	7	2	217.33
8	2	120.24	8	2	217.33
9	2	120.24	9	2	217.33
10	2	120.24	10	2	217.33
11	2	120.24	11	2	217.33
12	2	120.24	12	2	217.33
13	2	120.24	13	2	217.33
14	2	120.24	14	2	217.33
15	2	120.24	15	2	219.8
16	2	120.24	16	2	219.8
17	2	120.24	17	2	217.33
18	2	120.24	18	2	219.81
19	2	120.24	19	2	219.81
20	2	118.22	20	2	219.81
21	2	118.22	21	2	219.81
22	2	118.22	22	2	219.81
23	2	118.22	23	2	219.81
24	2	118.22	24	2	219.81
25	2	120.24	25	2	219.81
26	2	120.24	26	2	219.81
27	2	120.24	27	2	219.81
28	2	120.24	28	2	219.81
29	2	120.24	29	2	219.81
30	2	120.24	30	2	219.81

In **Table 2**, tests were carried out on clear water symbolized by the number 2 twice, namely at 10:00 am and 7:00 pm, which aims to determine the difference between morning and night light. In this experiment, each test was carried out 30 times with a time lag of five seconds. The turbidity of the pool water in the morning sensor value is 118.22 to 120.24. At night it can be seen from **Table 3** based on 30 tests, the turbidity level of the pool shows clear water with a value of 215.15 to 219.81, which shows that light has a significant effect on sensor readings.

Discussion: The SEN0189 sensor works on the principle of light transmission, where the sensor emits light and detects how much is transmitted or scattered by particles in the water. During the day, natural lighting helps the sensor to detect the clarity of the water more accurately, but at night, the low

light intensity causes distortion of the reading, so the sensor value increases even though the water remains clear. The test results indicated that the sensor showed less accurate readings in dark conditions, as the results did not match the physical reality of the water. This indicates that the sensor is greatly affected by ambient light, especially when used without artificial lighting.

Overall tool testing

Testing is done to ensure that all sensors are functioning properly, so all actions are not performed simultaneously.

Table 3. Overall tool data analysis

No	Turbidity	Float Switch 1 Condition	Float Switch 2 Condition	Servo	Actions taken	Solenoid Valve Action	Information
1	Very clear water	Off	Off	Off	No draining	No filling	Suitable
2	Very clear water	Off	Off	Off	No draining	No filling	Suitable
3	Very clear water	Off	Off	Off	No draining	No filling	Suitable
4	Very clear water	Off	Off	Off	No draining	No filling	Suitable
5	Very clear water	Off	Off	Off	No draining	No filling	Suitable
6	Very clear water	Off	Off	Off	No draining	No filling	Suitable
7	Very clear water	Off	Off	Off	No draining	No filling	Suitable
8	Very clear water	Off	Off	Off	No draining	No filling	Suitable
9	Very clear water	Off	Off	Off	No draining	No filling	Suitable
10	Very clear water	Off	Off	Off	No draining	No filling	Suitable
11	Clear water	Off	Off	Off	No draining	No filling	Suitable
12	Clear water	Off	Off	Off	No draining	No filling	Suitable
13	Clear water	Off	Off	Off	No draining	No filling	Suitable
14	Clear water	Off	Off	Off	No draining	No filling	Suitable
15	Clear water	Off	Off	Off	No draining	No filling	Suitable
16	Clear water	Off	Off	Off	No draining	No filling	Suitable
17	Clear water	Off	Off	Off	No draining	No filling	Suitable
18	Clear water	Off	Off	Off	No draining	No filling	Suitable
19	Clear water	Off	Off	Off	No draining	No filling	Suitable
20	Clear water	Off	Off	Off	No draining	No filling	Suitable
21	Clear water	On	On	On	Perform draining	Doing the filling	Suitable
22	Murky water	On	On	On	Perform draining	Doing the filling	Suitable
23	Murky water	On	On	On	Perform draining	Doing the filling	Suitable
24	Murky water	On	On	On	Perform draining	Doing the filling	Suitable
25	Murky water	On	On	On	Perform draining	Doing the filling	Suitable
26	Murky water	On	On	On	Perform draining	Doing the filling	Suitable
27	Murky water	On	On	On	Perform draining	Doing the filling	Suitable
28	Murky water	On	On	On	Perform draining	Doing the filling	Suitable
29	Murky water	On	On	On	Perform draining	Doing the filling	Suitable
30	Murky water	On	On	On	Perform draining	Doing the filling	Suitable

Testing of all devices is done to ensure that all sensors are functioning properly, so not all operations are done at the same time. Table 3 shows that the operations performed were in accordance with the aquaponic pond arrangement. To avoid overlapping the many processes used in one hydroponic unit, each process is not routinely carried out at the same time. The overall test of the device is appropriate.

Discussion: In very clear to clear water conditions (samples 1-20), the things that can be concluded are: (1) Float switches are off, indicating that the water level is still at normal limits, (2) Servo and solenoid valves are also off, meaning that no draining or filling is done, (3) The system automatically takes no action, and all results are in accordance with the expected control logic. In murky water conditions (samples 21-30), the things that can be concluded are: (1) Both float switches are on, indicating the system recognizes an abnormal condition, (2) Servo is active, automatically draining the water, (3) Solenoid valve is active, indicating the system is refilling the water, (4) All actions are performed automatically and in accordance with the conditions. This test also confirmed that each process was executed sequentially, with no overlap between draining and filling. The entire set of device actions showed consistent and appropriate results from 30 tests.

4. CONCLUSION

This research successfully designed and implemented an automatic control system to monitor and regulate the water turbidity level in aquaponic ponds using SEN0189 sensor, float switch, and IoT-based microcontroller (ESP8266 and Firebase). The system is able to identify changes in water turbidity levels in real-time and take automatic actions such as draining and refilling water. The test results show that: (1) The SEN0189 sensor provides a sensitive and accurate response to changes in water turbidity due to the addition of fish feed, (2) Reading errors only occurred in 8% of 98 tests, indicating a sensor success rate of 92%, (3) The influence of environmental light is significant, where sensor readings at night tend to be higher even though the water remains clear, so lighting is an important factor in the accuracy of readings, (4) The system successfully executes automatic water draining and refilling actions without overlapping between processes, with an operational success rate of 100% in the overall device test. Overall, the system designed in this study proved to be effective and reliable in maintaining water quality in aquaponic ponds, and can be integrated into an IoT-based monitoring system that is efficient and easy to control remotely.

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